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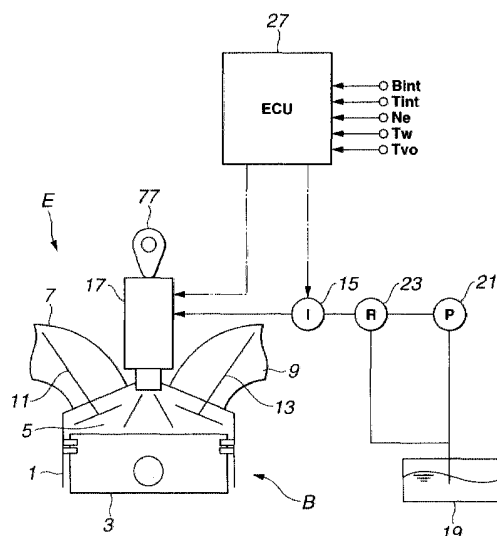
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(54) **Compression self-ignition internal combustion engine and fuel supply device therefor**

(57) A compression self-ignition internal combustion engine in which combustion of air-fuel mixture in a combustion chamber is made upon self-ignition of the air-fuel mixture under compression by a piston. A high temperature air-fuel mixture field is formed in the combustion chamber, and has a fuel concentration which

causes no self-ignition within the combustion chamber. A mixture charge injector is disposed to supply to the air-fuel mixture field a mixture charge which has a fuel concentration higher than that in the air-fuel mixture field and contains fuel and a fluid containing air, at least a part of the fuel being vaporized.

FIG.1



Description

BACKGROUND OF THE INVENTION

[0001] This invention relates to improvements in a compression self-ignition internal combustion engine configured to accomplish combustion of air-fuel mixture in a combustion chamber upon self-ignition under compression by a piston, and to a fuel supply device for supplying fuel into the combustion chamber of the engine.

[0002] In general, recent gasoline-fueled internal combustion engines tend to be operated on lean air-fuel mixtures for the purpose of promoting fuel economy. However, there exists a lean limit for air-fuel mixture because the lean-fuel mixture makes unstable combustion made upon spark ignition by a spark plug and flame propagation. Additionally, during lean burn or combustion of lean air-fuel mixture, a catalyst for exhaust gas purification cannot exhibit a high exhaust gas purification effect, particularly reduction of NO_x, as compared with that in combustion of stoichiometric air-fuel mixture.

[0003] To solve the above problems, a compression self-ignition internal combustion engine has been proposed as disclosed in Japanese Patent Provisional Publication No. 7-332141, in which combustion upon self-ignition is made under compression of a piston thereby achieving lean burn and low exhaust emission. In such a compression self-ignition engine, ignition timing is affected by difference in fuel amount to be supplied to the combustion chamber, i.e., difference in air-fuel ratio. Therefore, a range in which optimum ignition timing can be obtained is narrow, so that preignition and/or misfire will occur outside the range.

[0004] In view of this, a compression self-ignition internal combustion engine is proposed to control the ignition timing in order to prevent preignition and/or misfire, as disclosed in Japanese Patent Provisional Publication No. 10-196424. In this engine, a control piston is movably disposed at an upper part of a combustion chamber. This control piston additionally compresses compressed air-fuel mixture in the combustion chamber in the vicinity of top dead center of a piston in a cylinder. Accordingly, the temperature of the air-fuel mixture can be transiently raised thereby making self-ignition of the air-fuel mixture. Such transient rising of the temperature of the air-fuel mixture may be accomplished by injecting liquid fuel for ignition purpose into air-fuel mixture so as to accomplish effective combustion in the combustion chamber, other than the above method using the control piston.

[0005] However, drawbacks have been encountered in the above conventional techniques. In case of the conventional technique of raising the temperature of the air-fuel mixture under compression by the control piston, it is necessary to drive the control piston at high speeds, which will require a large-sized device for driving the control piston thereby increasing production cost. In case of the conventional technique of supplying the liq-

uid fuel, although the above problem can be solved, the temperature of the air-fuel mixture is lowered owing to vaporization latent heat under vaporization of the liquid fuel, which may lead to no self-ignition. This narrows a range in which the ignition timing is controllable.

SUMMARY OF THE INVENTION

[0006] In view of the above, it is an object of the present invention to provide an improved compression self-ignition internal combustion engine, which can overcome drawbacks encountered in conventional compression self-ignition internal combustion engines.

[0007] Another object of the present invention is to provide an improved compression self-ignition internal combustion engine in which a timing of self-ignition can be easily controlled while requiring no large-sized driving device for an auxiliary device such as a control piston.

[0008] A further object of the present invention is to provide an improved fuel supply device for a compression self-ignition internal combustion engine, which can supply a mixture charge containing fuel whose at least a part is vaporized, into a combustion chamber so as to suppress a temperature lowering in the combustion chamber.

[0009] An aspect of the present invention resides in a compression self-ignition internal combustion engine comprising a piston defining a combustion chamber in which a high temperature air-fuel mixture field is formed. The air-fuel mixture field has a fuel concentration which causes no self-ignition within the combustion chamber. Additionally, a device is provided for supplying to the air-fuel mixture field a mixture charge which has a fuel concentration higher than that in the air-fuel mixture field and contains fuel and a fluid containing air, at least a part of the fuel being vaporized. In the engine, combustion of air-fuel mixture in the combustion chamber is made upon self-ignition under compression of the piston.

[0010] Another aspect of the present invention resides in a compression self-ignition internal combustion engine comprising a piston defining a combustion chamber in which a high temperature air-fuel mixture field is formed. The air-fuel mixture field has a fuel concentration which causes no self-ignition within the combustion chamber. A passage through which a fluid containing air is supplied from the combustion chamber is provided. A fuel injector for injecting fuel is provided. Additionally, a mixture charge injector is provided having a mixture charge chamber connected to the passage and the fuel injector so as to be supplied with the fluid and the fuel to form a mixture charge which has a fuel concentration higher than that in the air-fuel mixture field, at least a part of the fuel being vaporized in the mixture charge. The mixture charge chamber is communicable with the combustion chamber of the engine so that the mixture charge is injected to the air-fuel mixture field in

the combustion chamber of the engine.

[0011] A further aspect of the present invention resides in a fuel supply device for a compression self-ignition internal combustion engine. The fuel supply device comprises a section defining a mixture charge chamber. A section is provided for introducing a fluid containing air from a combustion chamber of the engine in compression stroke of a cylinder of the engine into the mixture charge chamber. A section is provided for introducing fuel into the fluid within the mixture charge chamber so as to prepare a mixture charge. Additionally, a section is provided for supplying the mixture charge to a high temperature air-fuel mixture field within the combustion chamber, the air-fuel mixture field having a fuel concentration which causes no self-ignition in the combustion chamber.

[0012] A further aspect of the present invention resides in a method of operating a compression self-ignition internal combustion engine. The method comprises (a) forming a high temperature air-fuel mixture field in a combustion chamber of the engine, the air-fuel mixture field having a fuel concentration which causes no self-ignition within the combustion chamber; and (b) supplying to the air-fuel mixture field a mixture charge which has a fuel concentration higher than that in the air-fuel mixture field and contains fuel and a fluid containing air, at least a part of the fuel being vaporized. Under the method, combustion of air-fuel mixture in the combustion chamber is made upon self-ignition under compression of a piston defining the combustion chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a schematic illustration of an embodiment of a compression self-ignition internal combustion engine according to the present invention;
 Fig. 2A is an explanatory view showing a manner for introducing fuel from a fuel injector to a mixture charge injector, usable in the engine of Fig. 1;
 Fig. 2B is an explanatory view similar to Fig. 2A but showing another manner for introducing fuel from the fuel injector to the mixture charge injector, usable in the engine of Fig. 1;
 Fig. 3 is a longitudinal sectional view of the mixture charge injector used in the engine of Fig. 1;
 Fig. 4A is a longitudinal sectional view of the mixture charge injector the same as that in Fig. 3, showing an operational state of the mixture chamber injector;
 Fig. 4B is a longitudinal sectional view similar to Fig. 4A but showing another operational state of the mixture charge injector;
 Fig. 4C is a longitudinal sectional view similar to Fig. 4A but showing a further operational state of the mixture charge injector;
 Fig. 5 is a timing chart illustrating operational tim-

ings of the mixture charge injector in terms of engine cycle, usable in the engine of Fig. 1;

Fig. 6 is a graphic representation illustrating an idea of the present invention in which self-ignition is made in a combustion chamber upon supply of the mixture charge to an air-fuel mixture field in the combustion chamber; and

Fig. 7 is a flow chart showing a control operation of an electronic control unit used in the engine of Fig. 1.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Referring now to Fig. 1 of drawings, an embodiment of a compression self-ignition internal combustion engine according to the present invention will be illustrated by the reference character E. The engine E comprises an engine main body B which includes a plurality of engine cylinders 1. Piston 3 is disposed movable in a reciprocating manner in each cylinder 1 so as to define combustion chamber 5. The engine main body is provided with intake air passageway 7 and exhaust gas passageway 9 which are respectively communicable with the combustion chamber through intake and exhaust valves 11, 13. Intake air is supplied through the intake air passageway into the combustion chamber, while exhaust gas is discharged from the combustion chamber through the exhaust gas passageway.

[0015] Mixture charge injector 17 serving as a fuel supply device is disposed for each combustion chamber 5 in such a manner that its tip end section projects at the central and upper portion of the combustion chamber. The mixture charge injector injects a mixture charge which is prepared by mixing air or air-fuel mixture introduced from the combustion chamber and fuel injected from fuel injector 15. Fuel injector 15 is supplied with fuel from fuel tank 19 through pressure regulator 23 under the action of fuel pump 21. The mixture charge to be injected from the mixture charge injector has a fuel concentration which is higher than that in an air-fuel mixture field formed in the combustion chamber. Additionally, at least a part of fuel in the mixture charge is vaporized. At the fuel concentration of the air-fuel mixture field, no self-ignition occurs though the air-fuel mixture is high in temperature.

[0016] Electronic control unit (ECU) 27 is provided to control an injection amount and an injection timing of fuel to be injected from fuel injector 15 and of the mixture charge to be injected from mixture charge injector 17. The injection amount is an amount of the fuel or the charge mixture to be injected. The injection timing is a timing at which the fuel or the mixture charge is injected. Sensors (not shown) are provided to detect an intake vacuum Bint of engine, an intake air temperature Tint, an engine speed Ne, an engine coolant temperature Tw and a throttle (valve) opening degree (or a required engine load) Tvo. The intake vacuum is a Vacuum generated at an intake system of the engine. The intake air

temperature is a temperature of intake air to be introduced into the combustion chamber. The engine speed is of the engine. The engine coolant temperature is a temperature of coolant in the engine. The engine coolant temperature may be replaced with an engine lubricating oil temperature or a transmission oil (fluid) temperature. The throttle opening degree is an opening degree of a throttle valve (not shown) in the intake system and corresponds to an engine load to be required.

[0017] Fuel injected from fuel injector 15 is introduced to mixture charge injector 15 in such manners as shown in Figs. 2A and 2B. In Fig. 2A, the tip end section of fuel injector 15 is directly installed to the mixture charge injector so that fuel is directly injected from the fuel injector into mixture charge chamber 29 of the mixture charge injector. In Fig. 2B, fuel injector 15 is connected through fuel passage 31 with mixture charge chamber 29. Check valve 33 for preventing a reverse flow of fuel is disposed at the tip end section of the fuel passage 31 which tip end section is connected to the mixture charge chamber. In the example of Fig. 2B, fuel injector 15 is disposed separate from mixture charge injector 17, which is effective in case that a space for installing the mixture charge injector 17 is narrow.

[0018] Fuel injector 17 is arranged as shown in Fig. 3. The fuel injector includes a generally cylindrical body 35 which is formed thereinside with mixture charge chamber 29. Pressure increasing piston 37 is disposed movable in a reciprocating manner inside mixture charge chamber 29 in order to increase the pressure within mixture charge chamber 29. Air chamber 39 is located above the mixture chamber 29 so as to be contiguous with mixture charge chamber 29. The air chamber is larger in diameter than the mixture chamber. Air chamber 39 is connected through air introduction passage 41 to combustion chamber 5 of the engine so that air or air-fuel mixture from the combustion chamber is introduced into the air chamber. Check valve 43 is disposed in air introduction passage 41. Check valve 43 includes a ball 47 which is biased leftward in the drawing by spring 45 so as to normally maintain the check valve at a closed state. When the ball is moved rightward against the biasing force of the spring under the pressure of air or air-fuel mixture flowing through the air introduction passage 41 which pressure is higher than a preset value of the spring, the check valve is changed from the closed state to an open state. Additionally, when the pressure of air or air-fuel mixture passing through the air introduction passage further rises over the preset value of the spring, the ball is further moved rightward, so that the check valve takes its closed state. As a result, a timing at which air or air-fuel mixture is introduced from combustion chamber 5 to air chamber 39 can be set in the latter half period of compression stroke in each engine cylinder.

[0019] Air chamber 39 is connected through a communication passage 49 with mixture charge chamber 29. Check valve 51 is disposed in communication pas-

sage 49 so as to prevent a reverse flow of air or air-fuel mixture in a direction of from mixture charge chamber 29 to air chamber 39. Mixture charge chamber 29 is communicable with or openable to combustion chamber 5 of the engine through injection hole 53. The injection hole is closable or openable by an injection valve member M. The injection valve member M includes a valve head section 55 which is contactable with a generally frustoconical wall (no numeral) defining injection hole 53 so as to close or open the injection hole. The valve head section is connected through a valve shaft 57 with armature 59 located in mixture charge chamber 29. Spring 61 is interposed between the armature 59 and an annular flat portion (no numeral) formed inside body 35 which flat portion is located above injection hole 53. Accordingly, injection valve member M is normally biased upward under the biasing force of spring 61 so as to close injection hole 53. Solenoid 63 is embedded in a wall of the body 35 and located around armature 59. The armature is arranged to be moved downward or upward under current supply control accomplished by electronic control unit 27, so that injection hole 53 is controlled to be opened or closed.

[0020] Flange or disc section 65 is integrally formed at the top portion of pressure increasing piston 37 and contactable with an annular flat portion (no numeral) formed between mixture charge chamber 29 and air chamber 39. Rod 67 is integrally connected to disc section 65 and extends upward and out of air chamber 39. The rod is provided at its upper end with spring retainer 69. Spring 73 is interposed between spring retainer 69 and annular rod guide 71 formed integrally inside the body 35 in order to bias piston 37 upward. Suitable sealing member is disposed at the inner periphery of rod guide 71 defining rod insertion hole 71a thereby securing sealing between the inner periphery of the rod guide and the outer periphery of the rod, though not shown. Additionally, similar sealing is made between the outer periphery of pressure increasing piston 37 and the inner periphery of body 35, though not shown. Spring retainer 69 is covered with cup-shaped tappet 75 on which cam 77 for driving pressure increasing piston 37 is rotatably disposed in contact with the tappet 75.

[0021] Manner of operation of mixture charge injector 17 will be discussed with reference to Figs. 4A, 4B and 4C.

[0022] In a state of Fig. 4A, air or air-fuel mixture is introduced from combustion chamber 5 into air chamber 39 while piston 35 descends to increase the pressure within mixture charge chamber 29. At this time, valve head section 55 of injection valve member M closes the injection hole; check valve 43 is opened; and check valve 51 is closed.

[0023] In a state of Fig. 4B, valve head section 55 of the injection valve member opens the injection hole so that the mixture charge increased in pressure within mixture charge chamber 29 is injected into combustion chamber 5. At this time, check valve 43 is closed; and

check valve 51 is closed.

[0024] In a state of Fig. 4C, air or air-fuel mixture introduced into air chamber 39 in the state of Fig. 4A is moved through communication passage 49 into mixture charge chamber 29 under ascending of pressure increasing piston 35. At this time, valve head section 55 of the injection valve member closes the injection hole; check valve 43 is closed; and check valve 51 is opened. With movement of air or air-fuel mixture into mixture charge chamber 29, fuel is injected or introduced from fuel injector 15 into mixture charge chamber 29.

[0025] Next, manner of control for operational timings of mixture charge injector 17 will be discussed with reference to Fig. 5 which includes a control manner (a) and another control manner (b). In the control manner (a), injection of the mixture charge is carried out once in each engine cycle for each engine cylinder so as to inject the whole amount of the mixture charge contained in mixture charge chamber 29. In the control manner (b), injection of the mixture charge is carried out twice in each engine cycle for each engine cylinder so as to inject two portions of the mixture charge separately upon dividing the mixture charge within the mixture charge chamber into the two portions. Both in the control manners (a) and (b), timings of introduction of air or air-fuel mixture into air chamber 39 is indicated at an upper column, while timings of introduction of air or air-fuel mixture into mixture charge chamber 29, timings of the mixture charge from mixture charge injector 17, timings of injection (introduction) of fuel from fuel injector 15 into mixture charge chamber 29, and the like timings are indicated at a lower column.

[0026] Both in the control manners (a) and (b), introduction of air or air-fuel mixture into air chamber 39 is carried out in the latter half period of the compression stroke in the engine cycle. By this, air or air-fuel mixture at high temperature and pressure is introduced into air chamber 39. Additionally, air or air-fuel mixture within combustion chamber 5 is released out of the combustion chamber in the latter half period of the compression stroke, i.e., into air chamber 39, and therefore the pressure within the combustion chamber of the engine lowers in the latter half period of the compression stroke thereby preventing early ignition within combustion chamber 5.

[0027] Then, the pressure within mixture charge chamber 29 is increased under descending of pressure increasing piston 37, in parallel with proceeding of compression stroke of the engine cycle. Thereafter, the mixture charge within mixture charge chamber 29 is injected into combustion chamber 5 of the engine.

[0028] After injection of the mixture charge, high temperature and pressure air or air-fuel mixture is moved through the communication passage 49 into mixture charge chamber 29 under ascending of pressure increasing piston 37. Concurrently with this, fuel is ejected and supplied from fuel injector 15 into mixture charge chamber 29. The supplied fuel within the mixture cham-

ber is promoted in vaporization by the high temperature and pressure air or air-fuel mixture moved from air chamber 39, in which the supplied fuel is mixed with air or air-fuel mixture to form a mixture charge. This mixture charge is increased in pressure and injected into combustion chamber 5 of the engine during the next engine cycle, in which the whole amount of the mixture charge is injected at one time as shown in the control manner (a), or the two portions of the mixture charge are separately injected respectively at separate two times as shown in the control manner (b). Thus, the mixture charge increased in pressure is injected into combustion chamber 5 during the next engine cycle, and therefore vaporization of fuel is accomplished in a time duration before injection of the mixture charge into the combustion chamber. This prolongs the time required for vaporization of fuel, thereby effectively promoting vaporization of fuel.

[0029] In case that air or air-fuel mixture is injected or introduced into air chamber 39 at a timing other than the latter half period of compression stroke, air or air-fuel mixture is low in temperature and pressure as it is so as to be insufficient to vaporize fuel, and therefore air or air-fuel mixture may be pressurized and heated.

[0030] Fig. 6 depicts an idea exhibiting advantageous effects of the present invention, in which the mixture charge is injected to the air-fuel mixture field A formed within combustion chamber 5 which air-fuel mixture field is high in temperature and has such a fuel concentration as not to occur self-ignition. The mixture charge to be injected from the mixture charge injector has a fuel concentration which is higher than that in the air-fuel mixture field A formed in the combustion chamber. Additionally, at least a part of fuel in the mixture charge is vaporized. It will be understood that the air-fuel mixture field A is formed in the combustion chamber by supplying fuel into combustion chamber 5 from a fuel injector (not shown).

[0031] By supplying to the air-fuel mixture field A the mixture charge B containing fuel whose at least a part is vaporized, the fuel concentration in the air-fuel mixture field A is raised while suppressing temperature-lowering owing to vaporization latent heat of fuel. This puts the air-fuel mixture field A into such a condition P as to initiate self-ignition. Therefore, a timing at which self-ignition occurs can be controlled by suitably controlling the injection timing of the mixture charge B.

[0032] In comparison with the above, if liquid fuel C for ignition is supplied into combustion chamber 5 as in a conventional technique, the fuel concentration in the air-fuel mixture becomes generally the same as that in the above condition P, as indicated as a condition Q; however, the temperature of the air-fuel mixture cannot be raised under the influence of the vaporization latent heat of the ignition fuel C so as not to occur self-ignition.

[0033] In the above compression self-ignition internal combustion engine of the present invention in which the self-ignition timing can be controlled, the mixture charge including air or air-fuel mixture and fuel whose part is

vaporized is injected into combustion chamber 5 of the engine by mixture charge injector 17. This makes unnecessary using a large-sized driving device for driving a control piston at high speeds as in a conventional technique.

[0034] Next, control manner of electronic control unit 27 will be discussed on the case where the mixture charge is divided into the two portions which are separately injected respectively at two times as shown in the control manner (b) in Fig. 5, with reference to a flowchart of Fig. 7.

[0035] First, electronic control unit 27 receives input of the intake vacuum B_{int}, the intake air temperature T_{int}, the engine coolant temperature T_w, the engine speed N_e, and the required engine load (throttle opening degree) T_{ov} which are detected respectively by the corresponding sensors, at step S1.

[0036] A bottom dead center pressure P1 and a bottom dead center temperature T1 within combustion chamber 5 are read from a map stored in a memory in the electronic control unit, in accordance with the intake vacuum B_{int}, the intake air temperature T_{int} and the engine coolant temperature T_w which have been input to the electronic control unit, at step S3. The bottom dead center pressure P1 is a pressure within the combustion chamber at bottom dead center of a piston in the cylinder. The bottom dead center temperature T1 is a temperature within the combustion chamber at bottom dead center of the piston in the cylinder.

[0037] Then, a combustion chamber pressure (or a pressure within the combustion chamber) P and a combustion chamber temperature (or a temperature within the combustion chamber) T are respectively calculated every any crank angle from the read bottom dead center pressure P1 and the bottom dead center temperature T1, at step S5. The combustion chamber pressure P and the combustion chamber temperature T are calculated by the following equations:

$$P = P1 \times (\varepsilon)^\kappa$$

$$T = T1 \times (\varepsilon)^{(\kappa-1)}$$

where ε is the compression ratio, and κ is the ratio of specific heat.

[0038] Consequently, a fuel concentration K in the air-fuel mixture field causing abnormal combustion in the combustion chamber is read from a map stored in the memory, in accordance with the engine speed N_e and the combustion chamber temperature T which have been determined above, at step S7. This fuel concentration K tends to become high as the combustion chamber temperature T is low and as the engine speed N_e is high.

[0039] Then, judgment is made as to whether or not the fuel concentration in the air-fuel mixture field A

formed after injection the whole amount of the mixture charge at one time so as to correspond to the fuel amount determined in accordance with the required engine load is higher than the above-mentioned fuel concentration K causing abnormal combustion in the combustion chamber, at step S9. In case that the fuel concentration is higher than the fuel concentration K, abnormal combustion such as early ignition is caused if the whole amount of the mixture charge is injected as it is. Consequently, the whole amount of the mixture charge is divided into two (first and second) portions which will be respectively injected at first and second times which are separate from each other. The first portion is controlled in amount so as to obtain the fuel concentration of the air-fuel mixture field A not higher than the above-mentioned fuel concentration K, and injected from mixture charge injector 17, at step S11. This prevents abnormal combustion from occurring in the combustion chamber of the engine. Thereafter, in order to meet a target engine load, the remaining fuel (or the second portion) of the mixture charge is injected from mixture charge injector 17 at a previously set timing (or the second timing), at step S13. The second (injection) timing of the mixture charge corresponds to initiation of combustion in the combustion chamber, thereby controlling the ignition timing of the air-fuel mixture within the combustion chamber. The above-mentioned control for the amount of the first and second portions of the mixture charge can be easily accomplished by controlling a time in which current is passed through solenoid 63 in the mixture charge injector 17.

[0040] In case that the fuel concentration in the air-fuel mixture field A formed after injection of the whole amount of the mixture charge at one time so as to correspond to the fuel amount determined in accordance with the required engine load is judged to be not higher than the above-mentioned fuel concentration K at step S9, the whole amount of the mixture charge in mixture charge chamber 29 is injected at one time at a previously set timing, at step 15.

[0041] Thus, the amount of the mixture charge injected at the first time and the number of injections for the mixture charge are decided in accordance with the engine operating conditions such as the combustion chamber temperature, the engine speed and the required engine load. This can prevent abnormal combustion in the combustion chamber and can control the timing of initiation of combustion throughout a wide engine operating range extending from a low engine load condition to a high engine load condition, thereby enlarging a range in which compression self-ignition engine operation is made.

[0042] As appreciated from the above, according to the present invention, at least a part of the fuel contained in the mixture chamber to be supplied to the air-fuel mixture field within the combustion chamber is vaporized. This suppresses a temperature lowering of the air-fuel mixture within the combustion chamber due to vaporization.

zation latent heat of the fuel, thereby facilitating self-ignition of the air-fuel mixture. Additionally, the mixture charge is supplied from the mixture charge injector into the combustion chamber, and therefore no large-sized device for driving an auxiliary device such as a control piston is required.

[0043] The entire contents of Japanese Patent Application P2000-219548 (filed July 19, 2000) are incorporated herein by reference.

[0044] Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, in light of the above teachings. The scope of the invention is defined with reference to the following claims.

Claims

1. A compression self-ignition internal combustion engine (E) comprising:

a piston (3) defining a combustion chamber (5) in which a high temperature air-fuel mixture field (A) is formed, the air-fuel mixture field having a fuel concentration which causes no self-ignition within the combustion chamber; and a device (17, 77, 41, 43, 45, 47, 15) for supplying to the air-fuel mixture field a mixture charge (B) which has a fuel concentration higher than that in the air-fuel mixture field and contains fuel and a fluid containing air, at least a part of the fuel being vaporized,

wherein combustion of air-fuel mixture in the combustion chamber is made upon self-ignition under compression of the piston.

2. A compression-self ignition internal combustion engine as claimed in Claim 1, wherein the supplying device (17, 77, 41, 43, 45, 47, 15) includes a mixture charge injector (17) for injecting the mixture charge into the combustion chamber, a device (41, 43, 47, 45) for introducing the fluid from the combustion chamber into the mixture charge injector, and a device (15; 15, 31, 33) for introducing fuel from a fuel injector into the mixture charge injector.

3. A compression-self ignition internal combustion engine as claimed in Claim 2, further comprising a device (27) for allowing the fluid from the combustion chamber to be introduced into the mixture charge injector at timing of latter half period of compression stroke in a first engine cycle of a cylinder of the engine.

4. A compression-self ignition internal combustion engine as claimed in any of Claims 1 to 3, further comprising a device (27, 63, M) for allowing the mixture charge to be supplied into the combustion chamber in a period including intake and compression strokes in a second engine cycle of the cylinder of the engine upon pressuring the mixture charge, the second engine cycle being subsequent to the first engine cycle.

5. A compression-self ignition internal combustion engine as claimed in any of claims 1 to 4, further comprising a device (27, 63, M) for allowing a first portion of the mixture charge to be supplied into the combustion chamber at a first time so as to obtain a target fuel concentration of the air-fuel mixture field, and for allowing a second portion of the mixture charge to be supplied into the combustion chamber at a second time after the first time so as to meet a target engine load, the target fuel concentration being set in accordance with an engine operating condition of the engine, the first and second portions constituting the mixture charge.

6. A compression self-ignition internal combustion engine as claimed in any of Claims 1 to 5, wherein the fluid containing air is air introduced from the combustion chamber.

7. A compression self-ignition internal combustion engine as claimed in any of Claims 1 to 5, wherein the fluid containing air is air-fuel mixture introduced from the combustion chamber.

8. A compression self-ignition internal combustion engine (E) comprising:

a piston (3) defining a combustion chamber (5) in which a high temperature air-fuel mixture field (A) is formed, the air-fuel mixture field having a fuel concentration which causes no self-ignition within the combustion chamber; a passage (41, 49) through which a fluid containing air is supplied from the combustion chamber; a fuel injector (15) for injecting fuel; a mixture charge injector (17) having a mixture charge chamber (29) connected to the passage and the fuel injector so as to be supplied with the fluid and the fuel to form a mixture charge (B) which has a fuel concentration higher than that in the air-fuel mixture field, at least a part of the fuel being vaporized in the mixture charge, the mixture charge chamber being communicable with the combustion chamber of the engine so that the mixture charge is injected to the air-fuel mixture field in the combustion chamber of the engine.

9. A fuel supply device (17) for a compression self-ignition internal combustion engine, comprising:

a section (35, 37) defining a mixture charge chamber (29);
a section (41, 43, 47, 45) for introducing a fluid containing air from a combustion chamber (5) of the engine in compression stroke of a cylinder (1) of the engine into the mixture charge chamber;
a section (15; 15, 31, 33) for introducing fuel into the fluid within the mixture charge chamber so as to prepare a mixture charge (B); and
a section (M, 53) for supplying the mixture charge to a high temperature air-fuel mixture field (A) within the combustion chamber, the air-fuel mixture field having a fuel concentration which causes no self-ignition in the combustion chamber.

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10. A method of operating a compression self-ignition internal combustion engine (E), said method comprising:

forming a high temperature air-fuel mixture field (A) in a combustion chamber (5) of the engine, the air-fuel mixture field having a fuel concentration which causes no self-ignition within the combustion chamber; and
supplying to the air-fuel mixture field a mixture charge (B) which has a fuel concentration higher than that in the air-fuel mixture field and contains fuel and a fluid containing air, at least a part of the fuel being vaporized,

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wherein combustion of air-fuel mixture in the combustion chamber is made upon self-ignition under compression of a piston (3) defining the combustion chamber.

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FIG.1

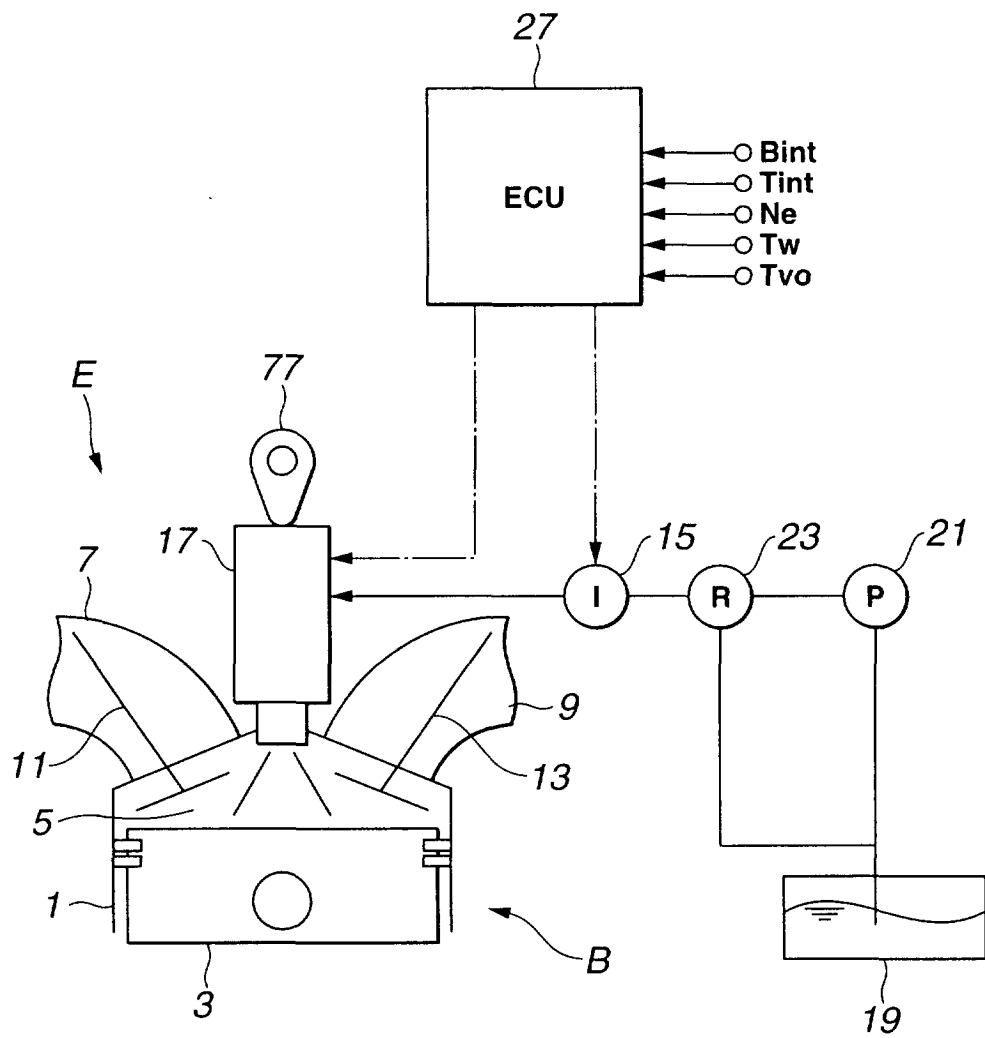


FIG.2A

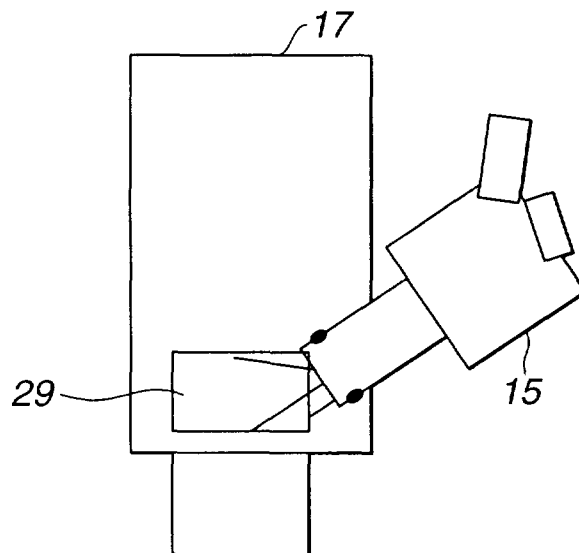


FIG.2B

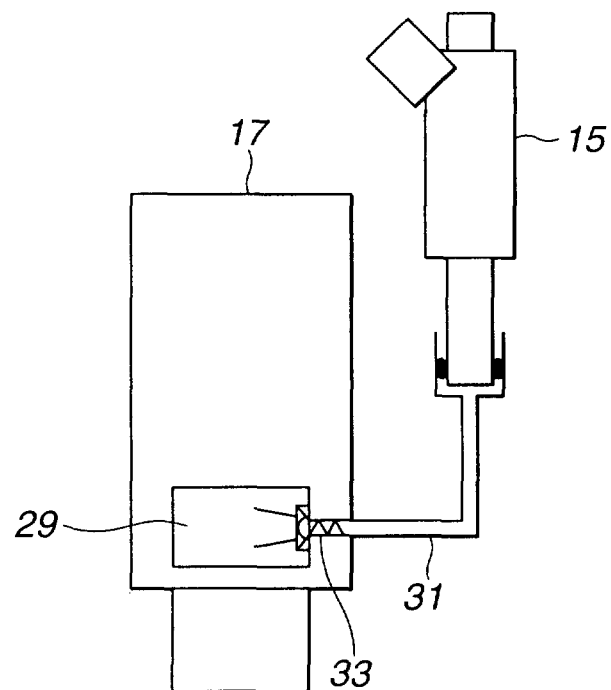


FIG.3

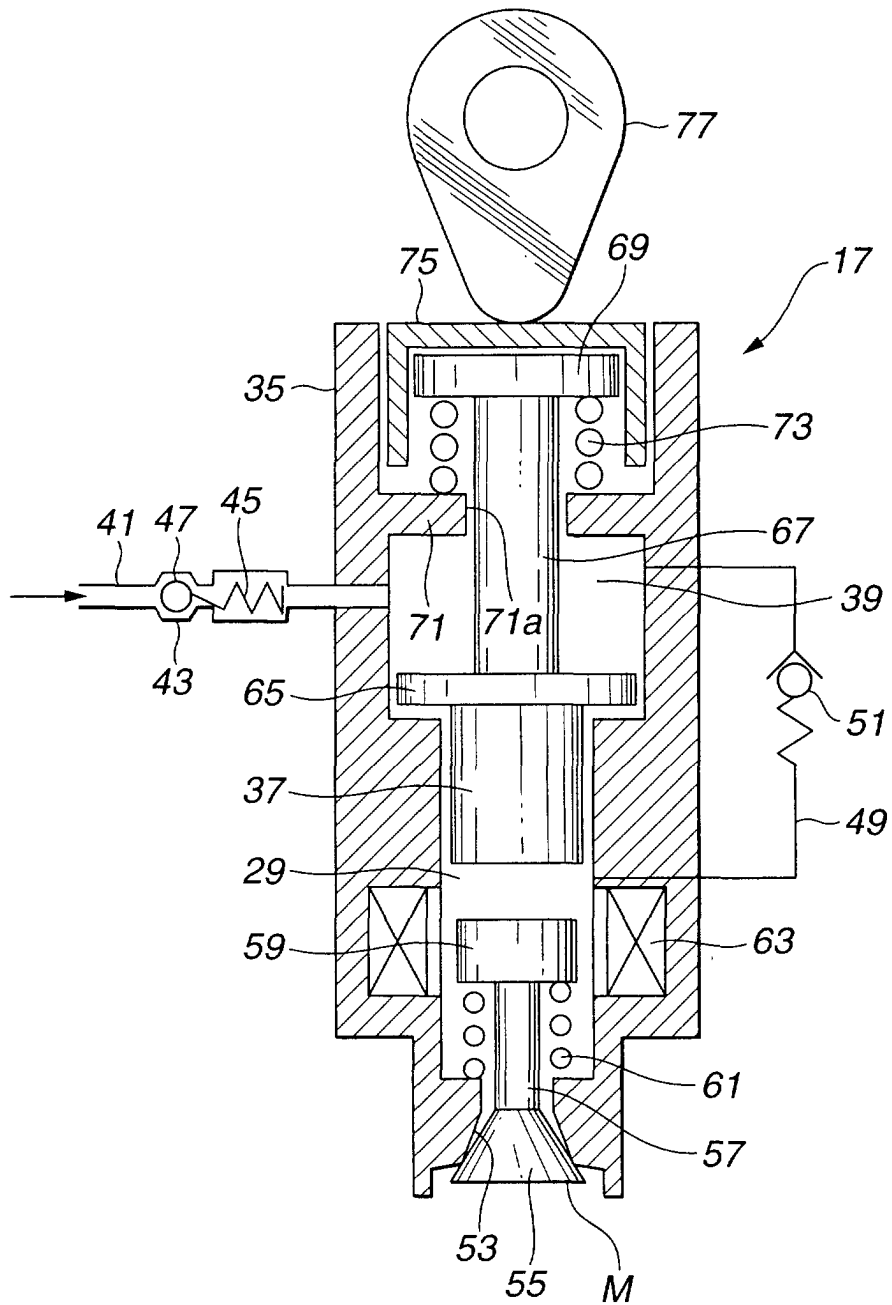


FIG.4A

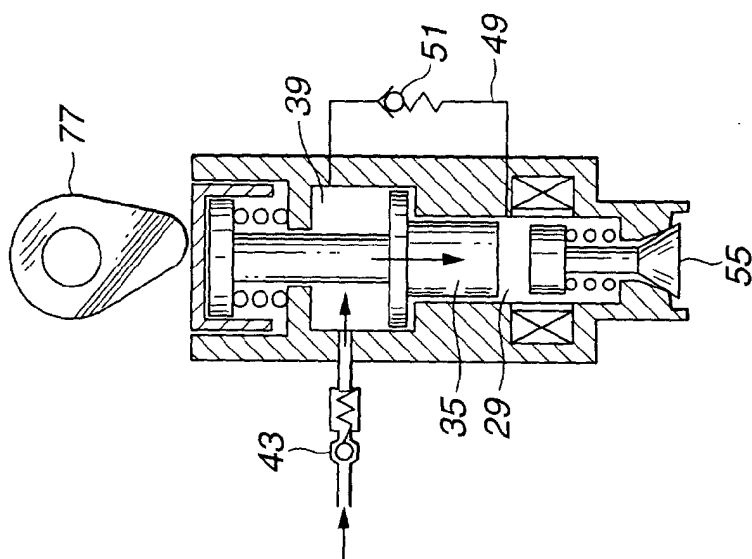


FIG.4B

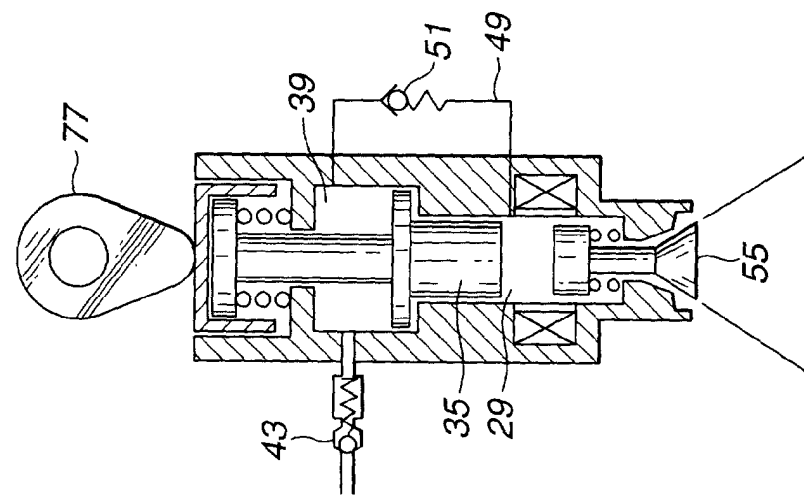


FIG.4C

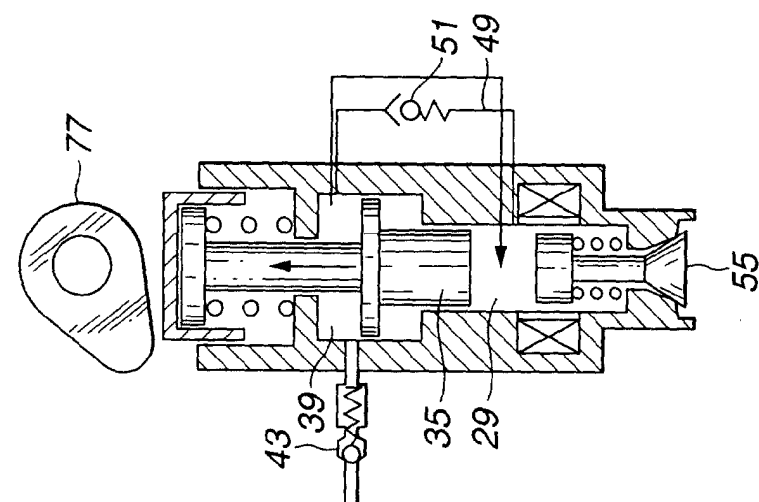


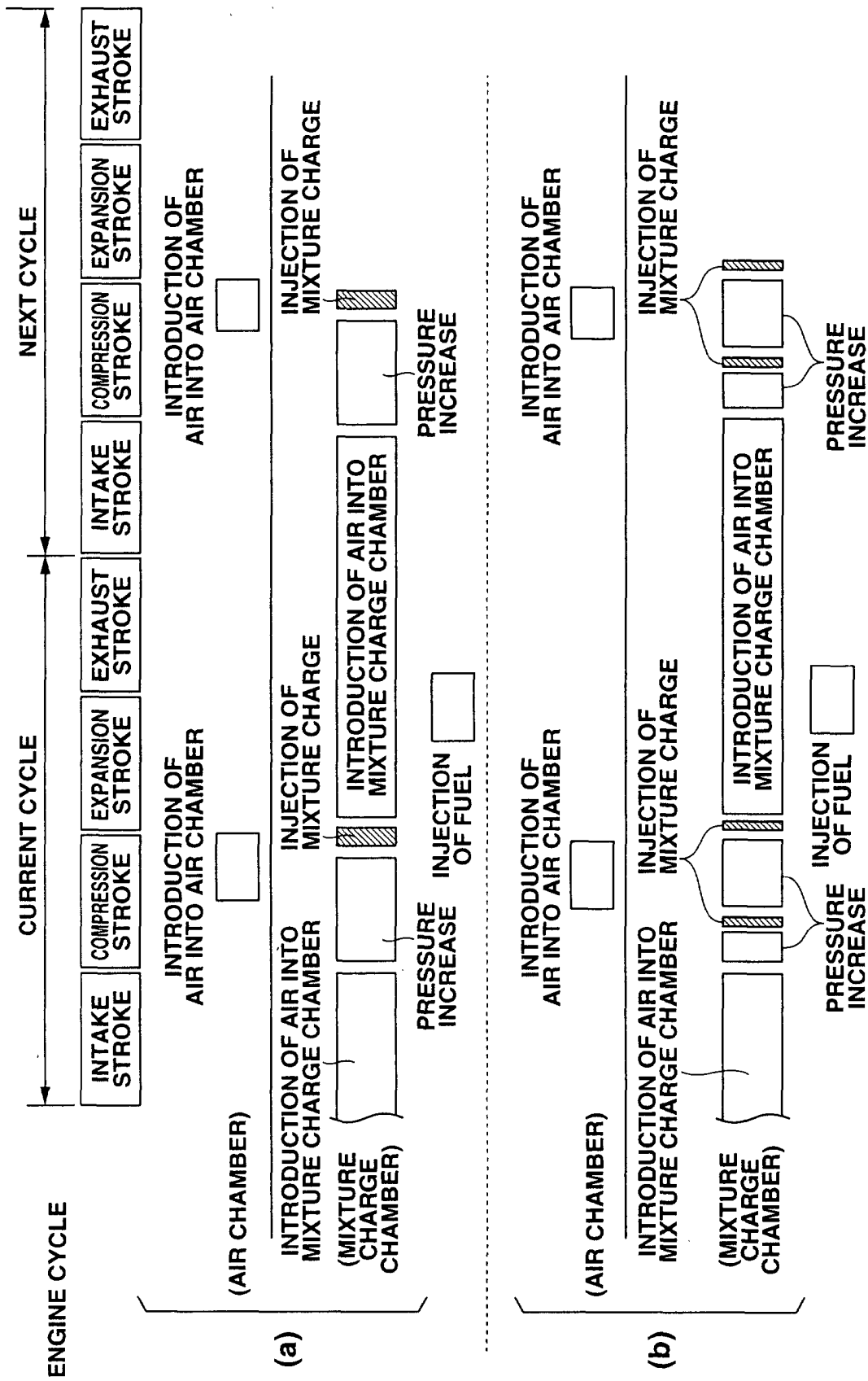
FIG.5

FIG.6

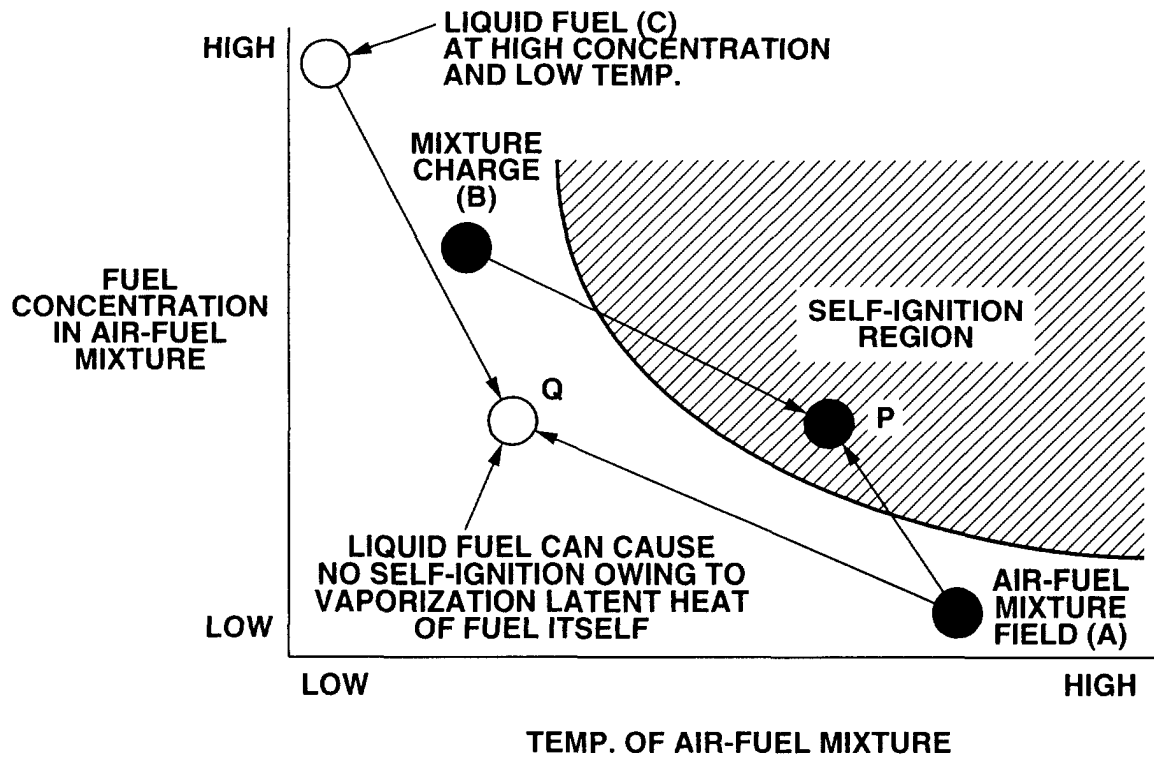


FIG. 7

